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Collection, Underwater Storage, and Disposal of Pleasurecraft Wastes

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COLLECTION, UNDERWATER STORAGE AND DISPOSAL OF PLEASURECRAFT WASTE

Feasibility of connecting sewage holding tanks on board recreational watercraft to a dockside collection system and storage in an underwater tank.

FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
DEPARTMENT OF THE INTERIOR

by

UNDERWATER STORAGE, INC.
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This report has been reviewed by the Federal Water Pollution Control Administration and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Federal Water Pollution Control Administration.

ABSTRACT

A pilot plant was designed, constructed and operated to show the feasibility of providing a facility for the collection, storage and disposal of waste from recreational watercraft.

An on-board holding tank was installed in each of ten boats for total impoundment of all effluent and for the connection to a dockside sewage collection system through a quick-connect coupling. Each boat was provided with a pump, tank and macerator. At dockside, each boat holding tank was pumped directly into a piped collection system.

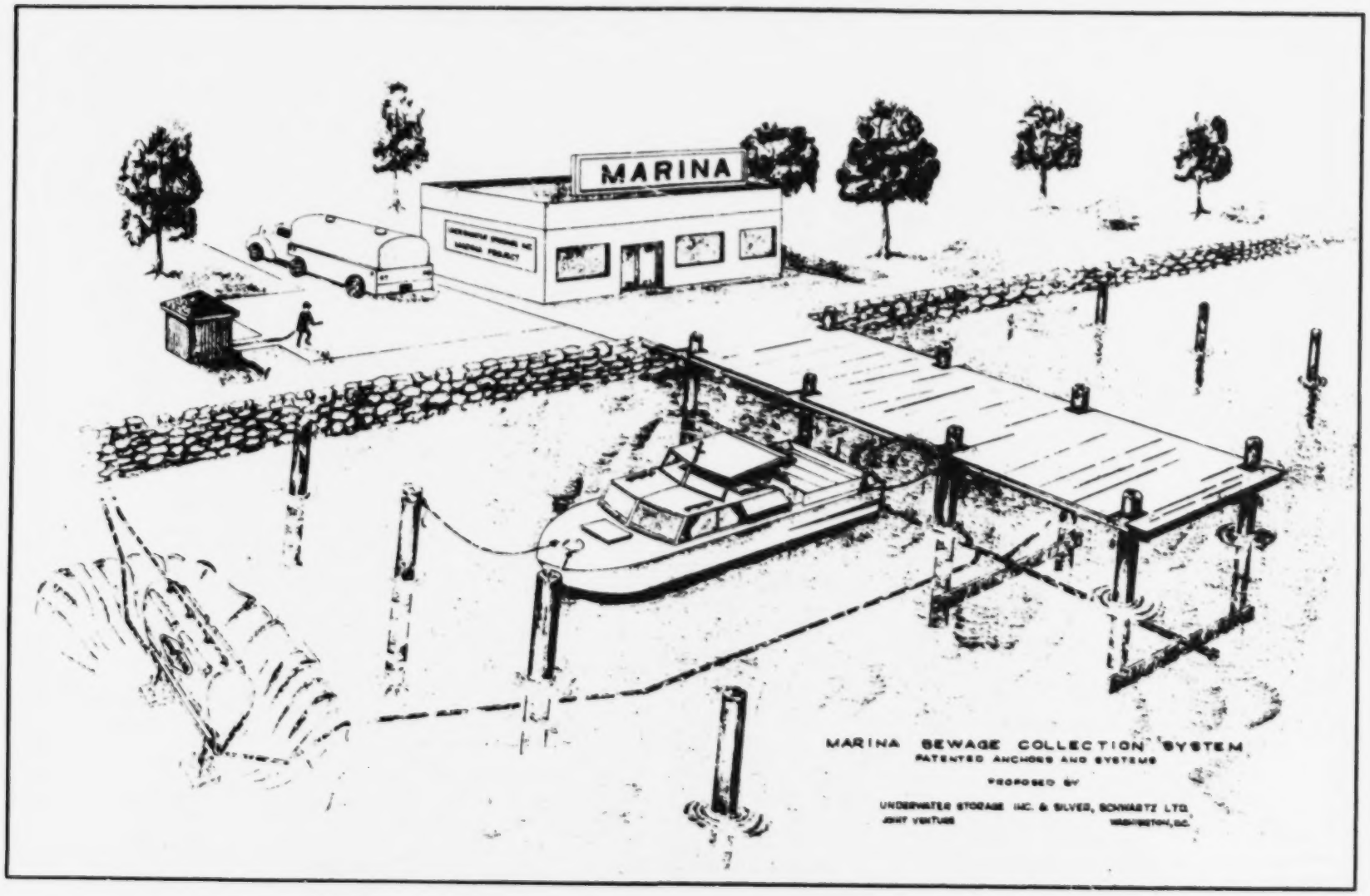
The dockside collection system was installed with a flexible hose connector at each slip for attachment to the respective boat. The collection system was installed for gravity flow to an underwater storage tank fabricated of synthetic rubber, impregnated with nylon fibers and fastened to the river bed by a system of patented anchors. The underwater storage tank received and held the effluent for periodic discharge by an on-shore pump station to sewage trucks for delivery to a sewage plant.

Flow meters were installed at the marina for recording waste flow to the underwater storage tank and amount extracted from the tank. Samples of waste material entering and leaving the

underwater storage tank were taken for laboratory analysis.

The project demonstrated that on-board storage of watercraft waste and subsequent discharge to an underwater storage tank was effective and economical. This project showed that the discharge of sewage from boats into rivers, lakes, waterways and estuaries could be eliminated.

This report is submitted in fulfillment of Contract No. 14-12-493 between the Federal Water Pollution Control Administration and Underwater Storage, Inc., Silver, Schwartz, Ltd., Joint Venture.



Rendering of Marina Showing Typical Boat Connection to Main Drainage Line and Extension to Underwater Storage Tank. Also shows Pump House and Septic Tank Truck.

Figure 1:

FIGURE 2. Rendering of marina collection system.

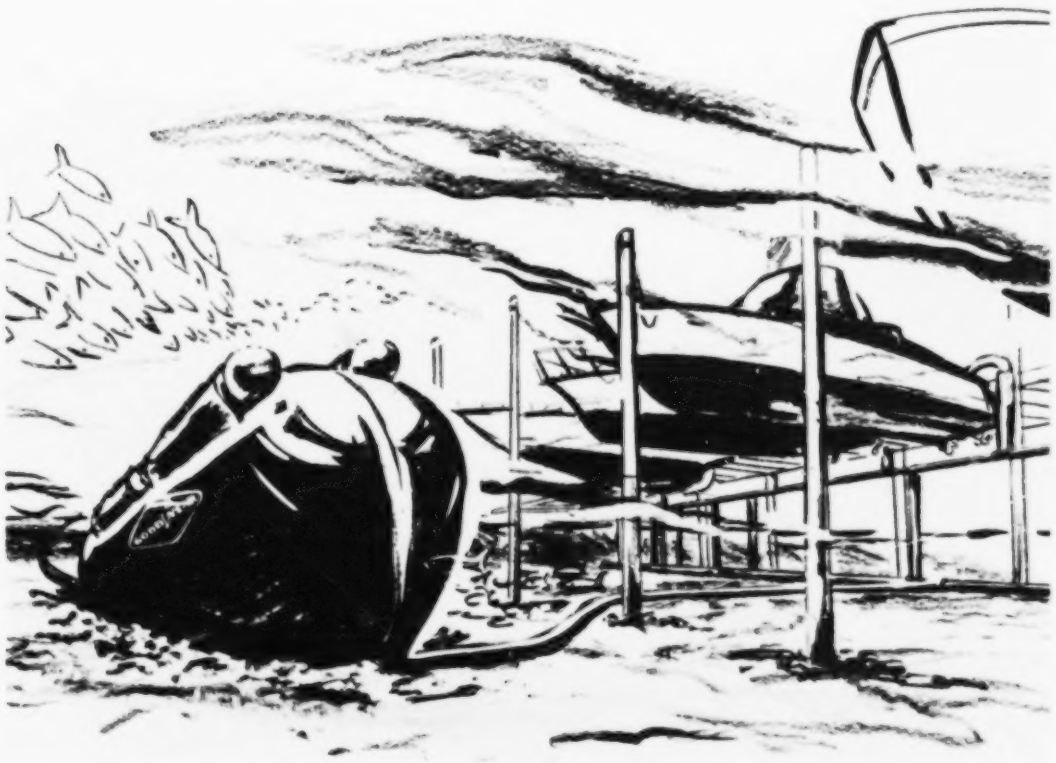


FIGURE 3. Fish-eye view of dockside collection system.

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SECTION I

CONCLUSION

The impoundment system, both on board recreational watercraft and at the marina, is moderately low in first cost and requires minimal attendance. Almost no maintenance is required on board boats, and the system is virtually tamperproof. The only maintenance required of the marina operator is at the pump and at the hose stations.

The entire system is simple to use by the boat owner, and is compatible with shore station techniques, such as dockside sewer lines, package treatment plant, or carry-off by septic tank trucks. The system is adaptable to expansion with increase in pumping facility, pipe size, or underwater storage tank capacity.

All materials used in the system can operate continuously in fresh or salt water without deterioration.

Existing watercraft which are provided with holding tanks could be adapted with minor modifications to provide means for discharging contents from the on-board holding tank to the dockside underwater storage tank. Boats without holding tanks would require more extensive work. It was found that the configuration of on-board holding tanks should be adapted individually

to the space availability of each boat.

Systems on board boats will have to be designed to function with various parameters such as number of heads and showers, galley facilities, and proposed boat occupancy. From these figures design tables can be formulated to encompass the type and number of boat facilities, length of boat, and occupancy.

In operation of the system, it was evident that all equipment located in the hold of a boat was subject to corrosion. Therefore, it is concluded that all materials used below deck must be non-corrosive type and motors must be closed type.

Equipment, particularly pumps, must be designed for actual watercraft usage and not based on standard laboratory or test stand capabilities. The human factor, it was found, had a great effect in use of equipment and must be taken into account in future installations.

The hose connector from the dock to the boat pump discharge fitting was found to leak a few drops of effluent upon disconnection. It was concluded, and successfully shown, this leakage could be stopped by the addition of a shut-off valve to the dock hose connection.

It was found the screw attachment, which was provided for connection of the hose station to the boat pump discharge fitting, created problems for boat owners. It was, therefore, concluded this attachment be replaced in future installations by a slip lock type connector for ease of use by the boat owner.

Dockside hose pipe used for connection from marina to boats must be of heavy duty material to withstand punishment imposed by boats butting against the pipe.

The underwater storage tank can be pumped out, washed out periodically from on-shore pumping equipment, and discharged to septic tank trucks, to an existing municipality sewage collection system, to a river barge collector, or to a waste treatment plant located within the vicinity of the marina.

The demonstration proved that the underwater storage concept of holding waste is feasible, economical, easy to install, and easy to operate. The installation does not interfere with waterways and is esthetically acceptable.

The installation demonstrated by the storage of waste, both on board and at dockside, present method of discharge of sewage from watercraft can be completely eliminated.

The average head flush on a boat, it was found, results in a flow of 1.5-gallons of water to the on-board storage tank. Average weekly waste flow from each boat was originally predicted to be 32.4-gallons, but in operation of the installation this was actually found to be an average of 46.5-gallons, or 44% greater than predictions. It was also found that the average population on some boats used for this demonstration was 5.0 and not 3.6 as set forth in available average criteria.

Of the ten boats used in the demonstration, seven boats never left their slips during the entire eight weeks of the operating period. This may not be average, but must be considered in design of marina pleasurecraft waste collection systems.

Size of underwater storage tanks for various marinas will depend on the number of boat slips being served and activity of the marina as related to transient watercraft; however, for purposes of basic planning, Table I on page 5 is recommended. Additional capacity will be required to serve waste from such shore facilities as restaurants, administrative offices, etc.

Cost for marina waste collection systems will vary from project to project depending on layout of boat slips with respect to

TABLE I

RECOMMENDED SIZE OF UNDERWATER STORAGE TANK

MARINA SIZE	TANK SIZE
50 Boat	3,000 gallons
100 Boat	6,000 gallons
150 Boat	9,000 gallons
200 Boat	12,000 gallons
250 Boat	15,000 gallons

TABLE II

WASTE COLLECTION SYSTEM COST ESTIMATES

MARINA SIZE	COST	COST PER BOAT SLIP
50 Boat	$ 44,000	$880
100 Boat	62,000	620
150 Boat	78,000	520
200 Boat	95,000	475
250 Boat	115,000	460

the service platform, construction of walkways, power availability, underwater storage tank location and dredging depth, main pumping station location, etc. Estimated cost for waste collection system, excluding sewage treatment plant, is found in Table II on page 5.

SECTION 2

RECOMMENDATIONS

It is recommended that all recreational watercraft having heads or galleys be provided with a storage tank for total impoundment of all waste, and no waste whatsoever be permitted to be discharged to the waterways. If boats do not have holding tank facilities, their heads should be padlocked until such time as these facilities are provided.

It is recommended that pump out facilities be provided at all marinas and not in boats. Marinas should also be provided with macerator units. This would not preclude boats presently having macerator units retaining them as an aid to operation.

It is recommended that at remote locations, or where discharge to a municipal sanitary sewer system is not feasible, package sewage treatment plants be considered for use in conjunction with marina collection and underwater storage systems. Size of these plants would not have to be full marina daily waste output. Since marinas only operate at maximum capacity during weekends, sewage treatment plant daily capacity should only have to be 25% of underwater storage capacity. For example, an installation with 9,000-gallons of storage should be provided with a sewage treatment plant having a capacity of only 2,250-

gallons per day. In this way not only will the plant be more efficient in operation, but will be less costly to install and operate.

In view of the large quantities of waste discharged from land based sources such as industry and municipalities, the precise effects of watercraft waste discharge are often masked and difficult to measure. This is especially true in large harbors or heavily populated or industrialized areas. In various areas it has been shown in sheltered harbors pollutional effects from watercraft waste constituted a hazard to body contact sports, such as swimming, and to shellfish culture. Even for waters used primarily, if not exclusively, for water-borne recreation, there is need for additional information on the effects of waste discharged from vessels. It is, therefore, recommended that studies be initiated on actual effects of watercraft waste on various sizes and types of waterways, lakes and harbors.

It is recommended that acceptable enforced regulations pertaining to pleasurecraft waste disposal be enacted as a major step in combating pollution to rivers, lakes, waterways and estuaries.

SECTION 3

INTRODUCTION

More than forty million people, it is estimated, have participated in recreational boating in the United States, each participant using waterways more than twice during 1968. Approximately 8.5-million recreational watercraft were in use, of which approximately 1.4-million were equipped with head facilities. A total of 5,700-marinas serve this huge fleet. There are also uncounted private ships and docking facilities in almost all United States waterways. Waste from recreational watercraft contributed more than one-third of all waste load and river pollution from all shipping in the United States.

The foregoing data was obtained from Boating Industry Magazine, The National Association of Engine and Boat Manufacturers, Inc., and Report of the Department of Interior, Federal Water Pollution Control Administration to the Congress of the United States, entitled "Waste from Watercraft".

It is readily seen that recreational watercraft have been a significant factor in the overall pollution picture. From information furnished by the Boating Industry Magazine, the number of recreational watercraft is increasing at the rate of 250,000-per year and waste load from these craft will result in

even greater contribution to present river pollution.

Various state laws are presently in force which prohibit any discharge of garbage, waste matter or refuse material of any kind or description whatever from watercraft. Some states have no laws or regulations for pollution control for watercraft. In such states, it is found, waste from recreational watercraft is discharged directly in the waterways with no retention or chemical treatment. In many states enforcement of pollution control is questioned.

Federal legislation does, in certain specified locations, prohibit the dumping of litter, sewage or waste matter. This is intended primarily to prevent impairment to navigation and the spread of communicable disease, animal disease, and plant pests. Pending Federal legislation will prohibit all dumping and should be more effective in preventing water pollution.

Recreational watercraft generally congregate for weekends, holidays and vacation periods in such numbers as to possibly seriously contaminate a shellfish area, beach or other critical water source which was previously uncontaminated, thereby affecting not only the health, but also the economical aspects

of a given area. They defile water areas presently used for water sports as swimming and water skiing, drinking water supply, shellfish beds and recreational lakes, by dumping large quantities of wastes in a concentrated area.

Sanitary waste may contain dangerous concentrations of organisms that can cause such diseases as dysentary, typhoid fever, gastroenteritis and hepatitis. Sewage, including sanitary waste and other waste water, is principally organic matter and its decomposition in water uses dissolved oxygen which must be maintained at levels satisfactory for the existence and propagation of healthy aquatic life. Human waste is rich in nitrogen and phosphorus nutrients which promote algae growths and surface scums of aquatic vegetation and accelerates entrophication. The pollutants may damage or destroy aquatic life and water fowl.

Recreational watercraft, when required by law, are provided with some means for retaining waste from heads and galleys in the form of holding tanks, recirculating systems, chemical treatment or disinfection. Widespread use of these boat facilities is dependent on adequate shoreside receiving facilities at marinas or waste treatment plants to receive, treat and dis-

pose of waste from boat holding tanks and containers. It is found that shore installations to serve recreational watercraft wastes are not generally available.

The most simple holding tank in a boat is a bucket sized container in which sewage material is collected and hand carried to the marina or dock for proper disposal. Large holding tanks require more sophisticated means for emptying and cleaning. These means are bulky and heavy and not readily available because of minimal available land based facilities.

Recirculating flush heads, similar to those used in aircraft, retain sewage for approximately one hundred usages, at which time they must be emptied at a shore station or overboard. Chemical toilets are similar to those used at construction projects. Waste is chemically treated and is retained in the tank until such time it can be emptied.

Macerator disinfectors mechanically grind up waste solids with surrounding river or sea water, and dose the mixture with disinfectant. The effluent is then discharged into the waterway after a brief period of contact. Disinfectors generally do not substantially reduce biological oxygen demand (BOD),

suspended solids or nutrient contents of the sewage before its discharge. The size of the particle of macerated sewage is such that it can still be recognized as such. The low level of treatment of macerator disinfectors may not be acceptable to the standards presently existing or of those being formulated.

The quantity of sewage discharge to a waterway is directly related to the number of watercraft occupants during a given period.

Based on a report, "Wastes from Watercraft", dated August 7, 1967, by the Department of Interior, Federal Water Pollution Control Administration, to the Congress of the United States, the average recreational watercraft greater than fifteen-feet in length carries 3.6 passengers and is away from port 5.6 hours or more per outing. An average rate of 2-1/2 uses per week for these boats during a 22-week boating season appears reasonable. Therefore, in an average week, not including day or overnight stays, each boat has an occupancy rate of fifty-man hours per week, or a little over two-man days. According to Civil Engineer Design Data Book, average daily per capita sewage flow in metropolitan residental areas amounts to approximately one hundred gallons per day, per

capita; on boat this reduces to approximately twenty-gallons per day. On this basis, two-man days will result in approximately forty-gallons of sewage flow for the average boat during a weekend.

SECTION 4

PROJECT SCOPE

The marina selected for the pilot project is located on the Anacostia River in Washington, D.C. (See Figure 10 on page 61.) It is operated under a concession permit with the National Capitol Park Service.

An agreement was entered into with the operator and owner of Long's Marine Service to construct, operate and test a pilot project serving a portion of the marina from July 1, 1969 to September 2, 1969. In addition, separate agreements were made with each of ten private boat owners for use of their boats to permit installation of on-board equipment as needed for the project.

The demonstration facility was designed, constructed and operated to show on-board holding tanks on recreational watercraft can be provided for retention of waste and these holding tanks can be connected and pumped to a marine or shoreside waste collection system in an economical manner, which is also simple to install and easy to operate. The shore facility was provided with an underwater storage container for shore collection and retention and final disposal of watercraft waste.

The installation has also proved that a shore collection system can be installed without interfering with waterways and can be esthetically acceptable; the only items visible were the hose stations at each boat slip and the pump house near the underwater storage tank, both designed to be pleasing in appearance.

As required by the scope of the project, a study was made of various watercraft heads and galleys to determine means for possible minor modifications for sewage holding facilities to function with shore collection installations.

Boats having on-board holding tanks or chlorinators, macerators or disinfectors can be adapted for pump out to a shore based marina sewage collection system by minor modification to the boat to provide an outlet for a quick-connect coupling to be made from the dock to the boat. Boats without holding tanks will require more extensive work to remove existing waste discharge pipe to waterway, to revamp piping at the head, and to accommodate a new holding tank.

Boats having galleys will require piping from galley to the on-board holding tank with built-in garbage grinder to prevent large particles from entering the tank.

TABLE III

BOATS USED FOR DEMONSTRATION

OWNER	REGISTRATION NO.	MAKE	LENGTH
Edwards, E.	MD-5523F	Chris Craft	25-foot
Elliott, H.	DC-2012A	Owens	27-foot
Jones, L.	DC-2150A	Pembroke	27-foot
Johnson, T.	DC-4536A	Revelcraft	30-foot
Lory, T.	DC-3546A	Chris Craft	27-foot
Martin, E.	DC-2670A	Owens	27-foot
Putman, H.	DC-3345A	Owens	26-foot
Sands, R.	DC-3306A	Chris Craft	25-foot
Williams, C.	DC-3595A	Chris Craft	27-foot
Williams, J.	DC-4586A	Pembroke	26-foot

As a basis for determining the capacity required for on-board storage tanks, it is found that the average head flush on boats results in a flow of 1.5-gallons of water. Based on the average head use by 3.6 passengers, four times per weekend outing, the total flow from heads is estimated to be 21.6-gallons. Therefore, the minimum size on-board holding tank should have a capacity of thirty-gallons, allowing some overage to prevent flooding.

When a galley is added to a boat, waste flow is estimated to increase by 50% or a total of 32.4-gallons. On this basis, a forty-gallon tank was used for on-board storage of all ten boats used in the demonstration.

In the ten-slip marina used for the demonstration, total estimated flow of waste from the ten boats, each equipped with heads and galleys, was 324-gallons per normal weekend, or 486-gallons for a three-day holiday weekend. Inasmuch as the collection system installed was designed to be extended for future use of fifty boats, total flow of the underwater storage tank was predicted at 2,430-gallons; therefore, a three-thousand-gallon underwater storage tank was used for the project.

The boats used for the demonstration all had heads and galleys. Tabulation is shown in Table III on page 17.

SECTION 5

COMPONENTS ON BOARD RECREATIONAL WATERCRAFT

Because of the need for expedient delivery to the demonstration project, on-board holding tanks were made of one size and configuration for all ten boats. Forty-gallon tanks were fabricated from polyvinyl chloride sheets. Physical size was standardized at 24-inches long by 20-inches wide by 15-inches high. Bolted covers were provided for access and connections were made for inlet, outlet and vent pipes as per Figure 11 on page 63. Facilities were provided for installation of a macerator unit in the tank.

Since on-board holding tanks were of one size, problems in the installation of the tanks on the boats were encountered. The tanks were located as close as possible to the center of the keel to prevent unbalanced weight as waste entered the tank. To do this required, in some instances, modifying, cutting or adding to hull frame to custom tailor each tank to the boat served. Actually, configuration of tank should be adapted to the boat.

Rubber hose piping from head and galley of each boat was rerouted to drain into the newly installed holding tank. Each installation was provided with a transfer valve to allow the

boat owner available means for bypassing tank and discharging waste into the waterway when stranded at a non-collecting facility. Of course, this feature would not be incorporated nor used where laws prohibit dumping, however, for this demonstration it was necessary since other marinas in the area have no facilities for accepting waste from watercraft.

Sea cocks were provided on all heads that were not originally provided with them. Copper traps and piping were added to galley sinks, and connections were made to thru-hull fittings with rubber hose. P.V.C. and nylon insert fittings were used with stainless steel clamps at each change of direction in the hose drainage system. When the galley sink was located across from the head, some problem in piping and drainage of the waste line resulted in connection to the holding tank. Each boat was separately planned for the installation.

Each holding tank was provided with a macerator located close to the outlet pipe connection. The macerators used were provided with standard manufacture open type, 12-volt motors located on top of the tank and provided with a 1/4-inch shaft through the tank cover. A standard bit extension was provided to obtain required depth in the tank. The shaft propeller for

macerating was made of stainless steel. Joining of shafts was accomplished by a steel sleeve coupling with two set screws. The shaft was rigid enough that a separate bearing was not required for the depth used. Some problems were encountered with the macerator, resulting in the conclusion that motors should be of closed type. Because of the damp environment, shafting and couplings should be made of stainless steel, thus preventing corrosion by the material contained in the holding tank. Time did not permit incorporating these features into the demonstration installation.

On-board transfer pumps selected for the project had a capacity for pumping 5 GPM at 10-foot head and 2 GPM at 30-foot head. This range permitted change because of tide movement. At low tide, the estimated total pump head of 6-feet indicated a flow of 6 GPM. On this basis, the pump-out time of 6-1/2-minutes could be predicted for the boat holding tank.

Each pump was provided with a 12-volt motor designed to be activated by a toggle switch on the boat control console when it was necessary to empty the contents of the holding tank.

Inlet and outlet of the transfer pump was tested under simulated

conditions on the laboratory stand. Tests showed the impeller, which was constructed with six neoprene fingers, would pass corn, toilet tissue, face tissue and a simulated soil made from oatmeal air-dried to a semi-rigid consistency. No test was made on the laboratory test stand on the human element.

In actual operation, pump suction blockage caused by bandaids, non-shred paper toweling, and feminine sanitary needs was encountered. To clear the system, it was necessary to empty the holding tank with a portable transfer pump so that the boat transfer pump could be removed and cleaned. A cut-off valve between tank and transfer pump should have been installed to facilitate easier servicing of a clogged condition.

Wiring for the boat macerator and transfer pump was taken from the 12-volt boat system. No. 12 gauge THW stranded wire was used in the installation. Motors were provided with in-line fuses for the amperage rating.

Standard marine fittings were used; finish was brass or chrome plate. All cuts through the hull were caulked with marine product caulk. Discharge connection from the transfer pump was through the hull below the coaming.

Figure 12 on page 65, and Figure 13 on page 67 show typical boat plan and components on boats.

SECTION 6

DOCK SIDE FACILITIES

Boat effluent was conveyed through a piping system installed along the boat dock. See Figure 14 on page 69. Standard weight galvanized pipe was used with victaulic coupling connections on main, and galvanized malleable screw fittings on branch piping to each boat slip. Boat connection was made of polyvinyl corrugated tube. At tube terminal a quick-coupling connector was provided which utilized a standard manufacture adaptor and a hose shank coupler. It was found that in order to prevent waste leakage from the polyvinyl corrugated tube on disconnection from the boat discharge fitting, it would be necessary to add a shut-off valve to be used for sealing off any waste flow after the on-board boat holding tank had been evacuated.

The quick-connect coupling on the end of each hose station was provided with a screw attachment for connection to the boat pump discharge fitting. It was observed there were problems in reluctance of the boat owners in accepting this type of fitting. As a result, the coupling should be changed on future installations to a slip lock type connector which is less complicated from the boat owners' viewpoint.

Polyvinyl corrugated hose at each slip was installed for convenience and for its transparent quality to enable visual inspection of flow from the boat transfer pump. It was noted the construction of boat slips and location of boats within the slips caused crushing and breaking of the hose because of boat handling in entering slips and because of tidal movements, necessitating several repairs during the period of operation. In future installations, dock side hose at boat slips should be rubber spiral wire reinforced, abrasive resistant, heavy duty hose.

For purposes of measuring flow from the boat slip stations to the underwater storage tank, a metering station was installed at the end of the marina on channel brackets mounted on piles. The metering station, also designed to serve as a sampling point, was constructed of steel plate to form a cylinder 30-inches in diameter by 60-inches high with a flat top and dished bottom, flanged inlet and outlet connections, access manhole and necessary openings for venting and sampling effluent.

In order to determine effluent flow, a dual float was installed in the tank with a single pole, single throw switch which

energized a 100-volt counter and a 100-volt solenoid valve. The float level was set at fifty-gallons of storage. Whenever the float reached the set point, a pneumatically operated butterfly valve on the discharge side of the tank was energized to dump effluent into the underwater storage tank. Dry nitrogen was utilized for the butterfly valve operation. Each time the metering tank was dumped, the counter recorder moved one digit By reading the counter and multiplying by fifty, flow over any given period could be determined.

Because of the rise and fall of the tide, it was found that the sea pressure would not allow a dump. As a result, the meter tank was modified to a closed system and a check valve was installed on the inlet to the tank. Several test runs indicated this solution was not satisfactory. It was finally determined a self-priming pump should be used to transfer the effluent from the meter station to the underwater storage tank, still maintaining the feature of counting dumps. This proved to be highly successful and should be the basis for future similar test procedures.

All control devices in connection with the metering station were mounted on a post at the end of the pier in a weather-

tight NEMA 3R enclosure.

Pipe for carrying effluent from the metering station to the underwater storage tank was standard manufacture pressure rated, flanged, reinforced rubber hose pipe. The same type pipe was used for connections between underwater storage tank and main shore side pumping unit.

The underwater storage tank was of special design by a patented Underwater Storage, Inc. concept and fabricated by Goodyear Tire and Rubber Company of synthetic rubber impregnated with nylon fibers. The tank was provided with a strongback for securing closure and for attachment to a patented anchoring system. The tank was provided with flanged connections for inlet, outlet and vent piping as indicated on Figure 15 on page 71. Flotation was built into the tank construction for buoyancy. Flotation tubes were controlled by a nitrogen source located in the shore side pump house.

Dredging for the underwater storage tank was accomplished from shore with the use of a clam to provide space in the river bed for tank and supports to be installed so as to maintain proper pitch of the collection system piping as well as proper clear-

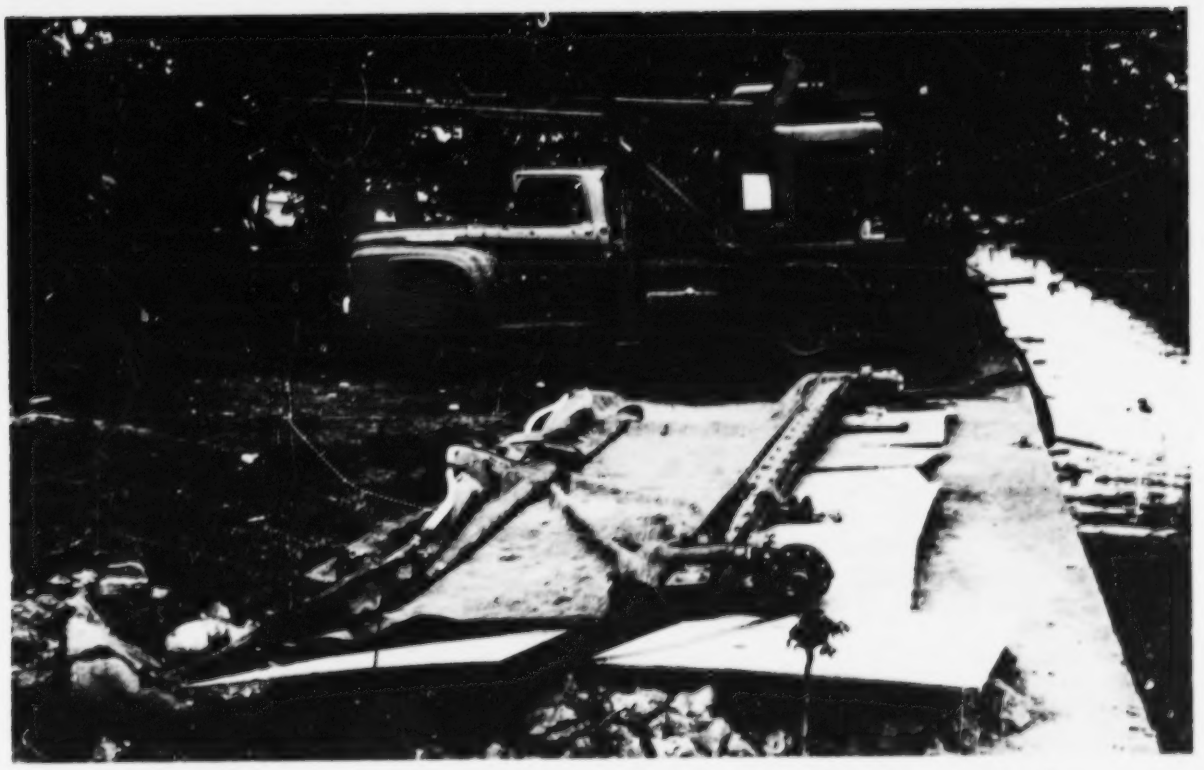


FIGURE 4. Underwater storage tank on ground ready for installation.

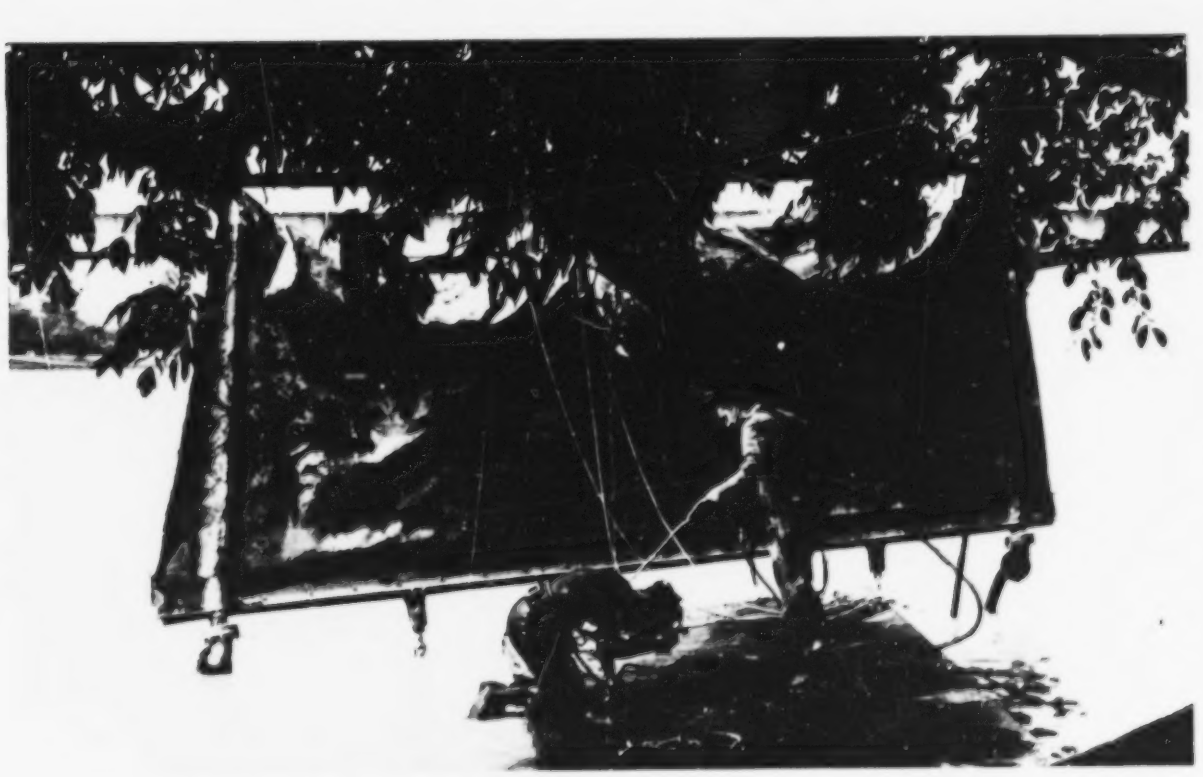


FIGURE 5. Underwater storage tank being lowered into river.

ance over tank. Tank location and dredging plan is shown on Figure 16 on page 73.

The pump house as shown on Figure 17 on page 75 was esthetically designed to blend into the landscape. The house contained main self-timing transfer pump, electrical service, nitrogen control station, and tank transfer piping. Discharge piping in the pump house incorporated valving, flow metering and underwater tank effluent flow sampling connection. A terminal adapter was provided through the wall of the pump house for water connection to a septic tank truck suction connection.

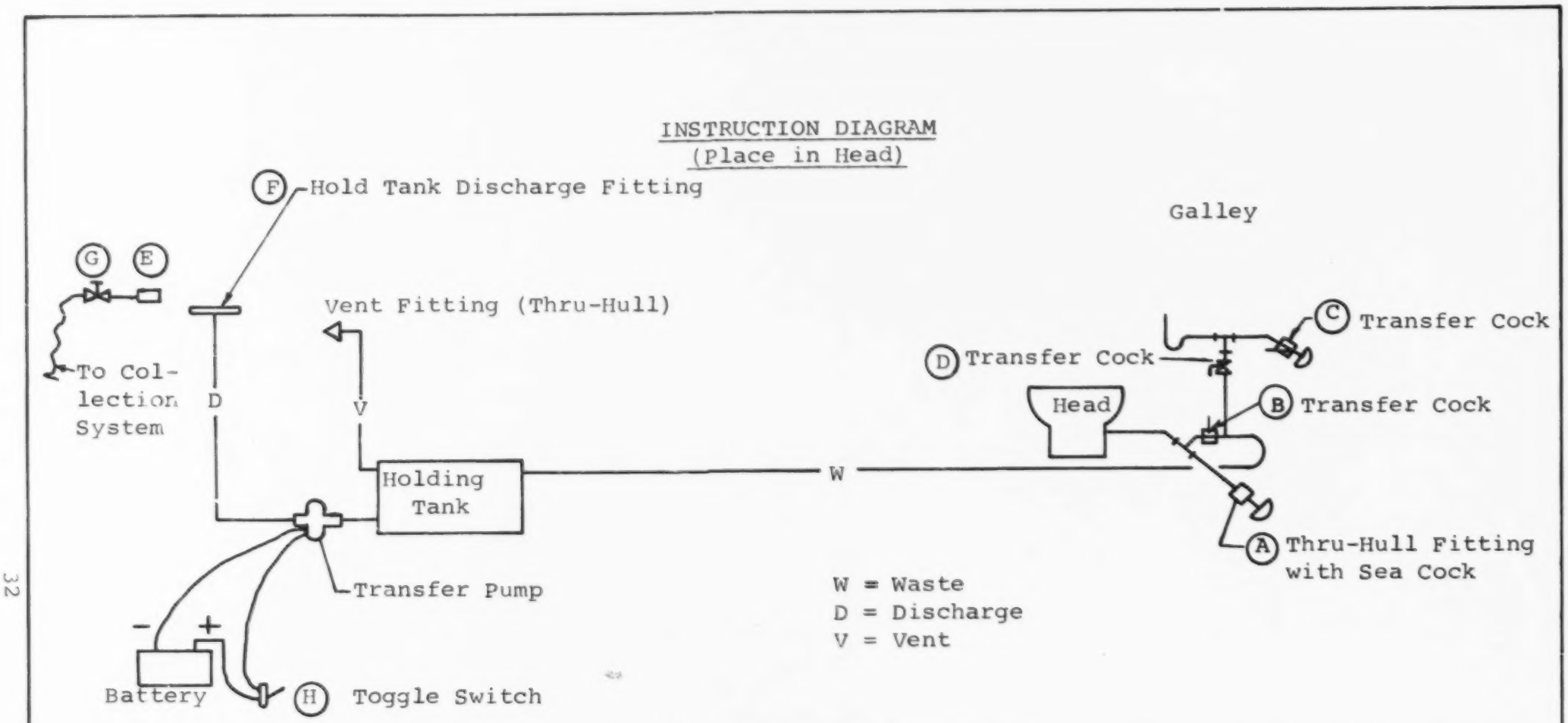
SECTION 7

OPERATION

Installation of the entire project was completed on June 27, 1969, and operation began on July 1, 1969. Boat owners were furnished with operating instructions and material location plan as shown on Figure 6 on page 32, and Figure 7 on page 33. The operating period for the demonstration ran through September 2, 1969.

The period from July 1, to July 9, was a breaking-in period, at which time various operational items were checked out. Based on the findings, the metering station was redesigned to provide a check valve in the discharge line and a self-priming pump to discharge flow from the metering station to the underwater storage tank. During the first week of operation, only 165-gallons (16.5-gallons per boat) were metered as flow to the underwater storage tank.

From July 9, to September 2, the installation operated relatively smooth except for problems on two boats. Whereas eight boat owners had no difficulty whatsoever in their pump operation from the boat holding tank to collector system, two operators had continuous problems, because of the manner in which they used their heads and galleys. One boat pump was



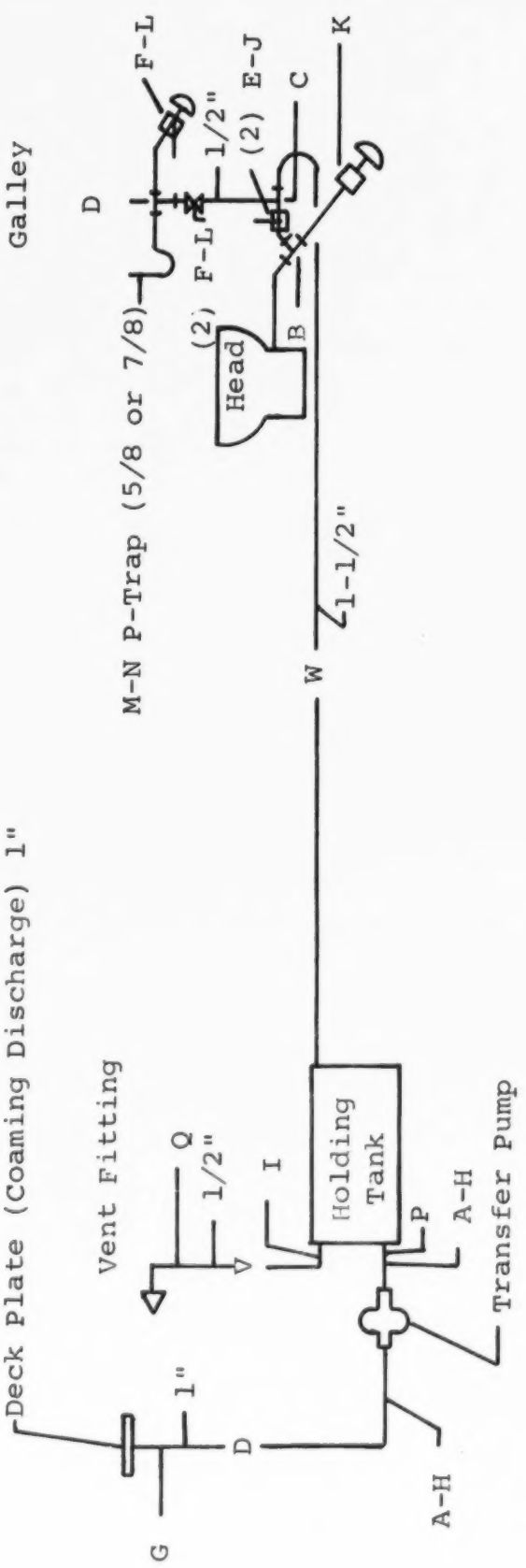
Maintaining Waste on Boat:
(Reverse Valves for Sea Discharge).

1. Close valves (A) and (C).
2. Open valves (B) and (D).

To Discharge Holding Tank to Collection System:

3. Remove Deck Plate (F).
4. Secure Discharge Hose Fitting (E) into (F).
5. Open Valve (G).
6. Activate Transfer Pump Toggle Switch (H).
7. When Holding Tank is Empty, Flush Head (ten strokes) to Purge Holding Tank.
8. Deactivate Toggle Switch (H).
9. System Now Ready for Reuse.

Figure 6:



LOCATION PLAN
MATERIAL FOR BOATS

Figure 7:

clogged no less than six times and its pump had to be removed and cleaned. The same boat had to be provided with a new macerator when a cloth hand towel was caught in the macerator blades. For all intent and purpose, this boat flow should not be fully counted in the system flow since it was out of use for the demonstration more often than it was in use.

In the second boat, guests flagrantly violated boat head and galley use (a dog bone was found in a burned out pump). The boat was out of service as far as the demonstration was concerned approximately 50% of the time. Therefore, for purpose of flow computation, 9.0 boats was used to arrive at a flow per boat per weekend.

On August 15, 1969 the underwater storage tank contents were pumped into the septic tank truck. Total metered flow to the truck was measured at 2,540-gallons, or 282-gallons per boat. Average weekly flow for the six-week period was found to be 47-gallons per boat.

Final pump out of the underwater storage tank was made on September 2, 1969, at the termination of the demonstration period. At this time 840-gallons, or 93-gallons per boat, were pumped. Average weekly flow for this final two weeks of the

demonstration was found to be 46.5-gallons per boat.

The average weekly waste flow from each boat was approximately 44% greater than the 32.4-gallons predicted. After the demonstration began, it was realized this particular group of ten boat owners was not at all average. At least five boats were in use every day for dockside get-togethers; the average population on these five boats was 5.0 and not 3.6 as set forth in available average criteria; and seven of the ten boats never left the boat slip during the entire eight weeks.

SECTION 8

CHEMICAL SAMPLES

All tests for chemical analyses were made by The C. W. England Laboratories, Inc., Washington, D.C. Tests were made by "Standard Methods for Examination of Water and Waste Water," 12th Edition, 1965, except as otherwise noted herein.

1. Coliform - E Coli - Standard Test A with the E Coli identified by selecting a representative number of colonies into E.C. Medium.

2. Biochemical Oxygen Demand - Section III, with oxygen determined - Section III, method A (Azide Modification).

3. Chemical Oxygen Demand - Section IV.

4. pH - Electrometrically adjusted to 25° C.

5. Alkalinity - Section III, method B (Potentiometric).

6. Suspended Solids - Section III, part C, using a glass mat.

7. Total Dissolved Solids - (Residue) - Section I, method C, using filtered sample.

8. Phosphorus - Method for Quantative Determination of Total Phosphorus in Filtered and Unfiltered Water. Gales, Julian, Kroner (U.S.P.H. Taft Center).

9. Nitrate - Section III, Method B.

10. Nitrite - Section III.

11. Ammonia Nitrogen - Section III, method B.

12. Chloride - Section III, method A.

Samples were taken at the meter station on the following dates:

Saturday	July 12	at 9:00 A.M. and 7:00 P.M.
Sunday	July 27	at 9:30 A.M. and 7:00 P.M.
Sunday	August 10	at 9:00 A.M. and 7:00 P.M.
Sunday	August 24	at 9:00 A.M. and 7:00 P.M.
Saturday	August 30	at 12:00 Noon.

Tabulation of these samples is found on Table IV on page 41.

Additional samples were taken at the pump house during the time the underwater storage tank contents were being pumped into the septic tank truck. Time and date for these samples are as follows:

Friday	August 15	at 9:15 A.M., 9:30 A.M., 10:00 A.M., and 10:15 A.M.
Tuesday	September 2	at 2:15 P.M.

Tabulation of these samples is found on Table V on page 43.

The chemical samples taken of the recreational watercraft sewage were not uniform and not typical of domestic sewage. Variations in characteristics may have been because of sampling techniques.

Biochemical oxygen demand was found to be higher than average for domestic waste. This is obviously because of higher con-

centrations of waste than found in municipal systems.

Settleable solids were found to fall in the range of less than 0.1 to 3.5 milliliters per liter for samples taken at the meter station. This is well below the range of domestic sewage flow because of maceration. Total dissolved solids, on the other hand, were found to be well above average because of high concentration.

The chloride content of the samples was found to be unusually high. A range of 20 to 150 milligrams per liter was expected; however, a number of the samples exceeded the high range. It was assumed this situation resulted from boats drawing water directly from the river. Tests of river water around the marina indicated chloride content to be low; ranging from 10 to 14 milligrams per liter. The only logical answer is the eating and drinking habits of people on board boats differ from those on shore. This, compounded with high concentration in the tank, resulted in the unusual chloride sampling.

It is noted that underwater storage of watercraft waste has no appreciable effect on waste characteristics. The initial sampling from the underwater storage tank effluent pumped to

the septic tank truck was found to be much greater than subsequent samples because suction from the underwater storage tank was taken from the bottom of the tank where concentration was greatest.

TABLE IV

CHEMICAL SAMPLES TAKEN AT THE METER STATION PRIOR TO FLOW INTO UNDERWATER STORAGE TANK

	SATURDAY, JULY 12		SUNDAY, JULY 27		SUNDAY, AUGUST 10		SUNDAY, AUGUST 24		SATURDAY AUGUST 30
	*9:00 A.M.	*7:00 P.M.	9:30 A.M.	7:00 P.M.	9:00 A.M.	7:00 P.M.	9:00 A.M.	5:00 P.M.	12:00 NOON
Coliform Bacteria @ 35° C. per 100 mil	< 3,000	3,000	480,000	840,000	3,200,000	2,900,000	120,000	160,000	4,200
E. Coli Bacteria @ 45.5° C. per 100 mil	< 3,000	< 3,000	20,000	60,000	170,000	60,000	30,000	30,000	860
pH @ 25° C.	7.18	7.21	8.24	8.28	7.98	7.95	8.62	8.65	8.42
BOD (mg/l)	25	30	90	120	120	100	220	220	1,100
COD (mg/l)	70.4	79.2	132	440	96	132	710	687	6,560
Alkalinity (mg/l)	78.0	94.0	156	164	244	241	1,743	1,827	2,017
Settleable Solids (ml/l)	0.6	0.04	0.5	3.5	1.1	1.0	< 0.1	0.7	110
Total Dissolved Solids (mg/l)	208	254	298	314	362	368	1,238	1,300	1,000
Total Phosphates (mg/l)	4.5	4.3	18.8	17.2	10.7	10.6	64.9	63.5	160
Nitrate (mg/l)	1.8	1.2	0.13	0.30	0.04	0.13	2.4	1.5	1.20
Nitrite (mg/l)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Ammonia Nitrogen (mg/l)	3.6	2.5	27.2	28.6	41.2	40.9	439.04	456.96	466.2
Chlorides (mg/l)	40.0	39.3	228	130	76.5	100.7	382.5	376.6	423.7

°C = Degrees Centigrade
mg/l = Milligrams per liter
ml/l = Milliliters per liter
< = Less than
* = Samples very heavily contaminated with petroleum products

TABLE V

CHEMICAL SAMPLES TAKEN AT PUMP HOUSE WHEN UNDERWATER STORAGE TANK CONTENTS WERE BEING PUMPED INTO SEPTIC TANK TRUCK

	FRIDAY, AUGUST 15				TUESDAY SEPTEMBER 2
	9:15 A.M.	9:30 A.M.	10:00 A.M.	10:15 A.M.	2:15 P.M.
Coliform Bacteria @ 35° C. per 100 mil	30,000	20,000	16,000	23,000	1,900
E. Coli Bacteria @ 45.5° C. per 100 mil	8,100	4,900	5,100	5,400	240
pH @ 25° C.	4.69	6.39	6.28	6.30	7.08
BOD (mg/l)	840	135	115	110	60
COD (mg/l)	770	115	107	140	160
Alkalinity (mg/l)	112	244	244	238	378.0
Settleable Solids (ml/l)	0.2	< 0.1	< 0.1	< 0.1	< 0.1
Total Dissolved Solids (mg/l)	6,902	310	298	312	296
Total Phosphates (mg/l)	505	13.9	14.8	11.5	12.6
Nitrate (mg/l)	3.76	0.31	0.89	0.80	0.53
Nitrite (mg/l)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Ammonia Nitrogen (mg/l)	271.6	49.0	47.0	47.3	68.6
Chlorides (mg/l)	588.5	80.7	74.1	71.8	235.4

°C. = Degrees Centigrade
mg/l = Milligrams per liter
ml/l = Milliliters per liter
< = Less than

SECTION 9

DISCUSSION

The most difficult problem to control, from the standpoint of the boat owner, is the action of guests who come aboard recreational watercraft. Each boat owner was instructed to dispose of nothing in the waste system other than that which had been eaten or drunk. Although each boat owner and his family observed this rule faithfully it was found that this was not the case with people who came aboard without such instructions. As a result, it was found that the use of on-board pumping and macerating equipment is not practical or advisable, as it adds initial cost for the boat owner as well as continual operating problems. Furthermore, it tends to defeat the purpose of holding on-board waste and results in unintentional dumping of waste because of filling up of the holding tanks.

It is, therefore, felt that pump-out stations with integral macerator units located at the marinas would much better serve the purpose. These stations could be coin operated to be financially attractive to the marina operator.

The hose stations at the boat slips must be provided with quick-connect features to eliminate excessive time for the boat owner to make connection. In addition, the hose station must be such

that no leakage or drippage occur before or after the on-board holding tank is pumped out. This was achieved at the demonstration facility by the installation of a hand operated valve at the end of each hose station as shown on Figures 8 and 9 on page 47.

The use of the underwater storage tank is found to be the major component of the entire system. Inasmuch as boating for leisure time is a weekend and holiday pastime for millions of Americans, there is no need to immediately treat or pump sewage to trucks, a municipal system, or a package sewage treatment plant. The sewage flow from a two-or three-day period can be treated over a period of seven days. Therefore, a sewage treatment plant serving a marina does not have to be sized for the maximum flow from recreational watercraft. The plant can be reduced to one-half the size or even less by the use of underwater storage. This reasoning becomes especially true when consideration is given to connecting such shore facilities as marina restaurants, locker rooms, toilets, etc., to the system. Here again, use of the overall marina complex is for large sewer waste flows over relatively short periods of time. It is not economical to build a sewage treatment plant for the peak flow, when one can be built for a fraction of the flow by the installation of under-

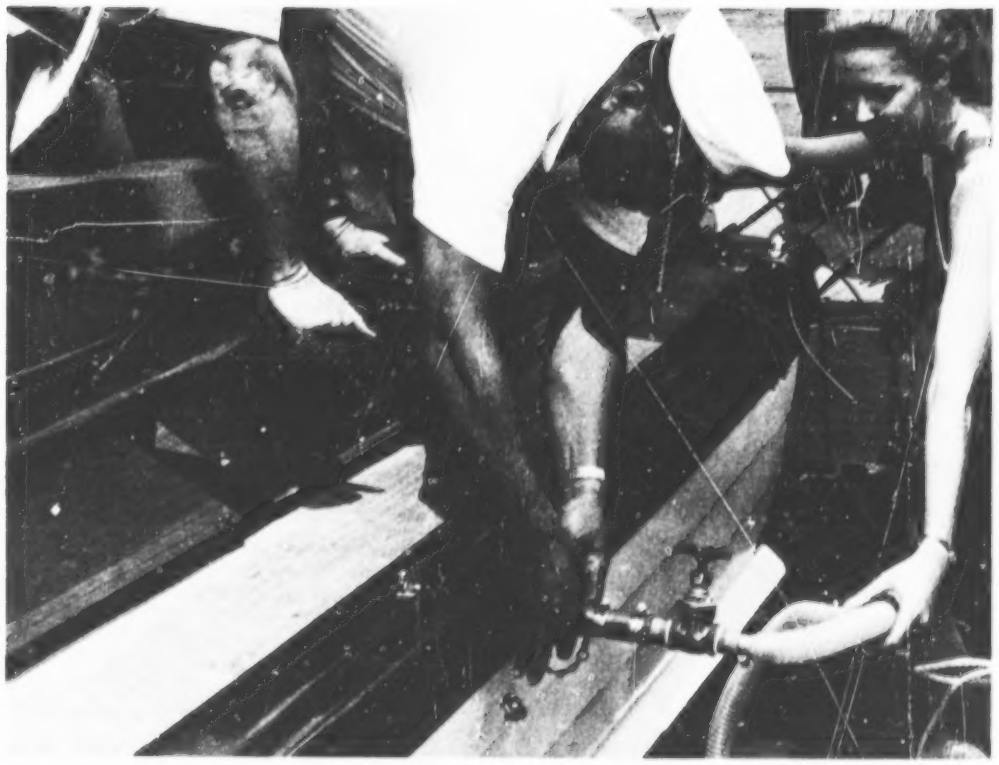


FIGURE 8. Connection of hose to boat discharge fitting at rear of boat.

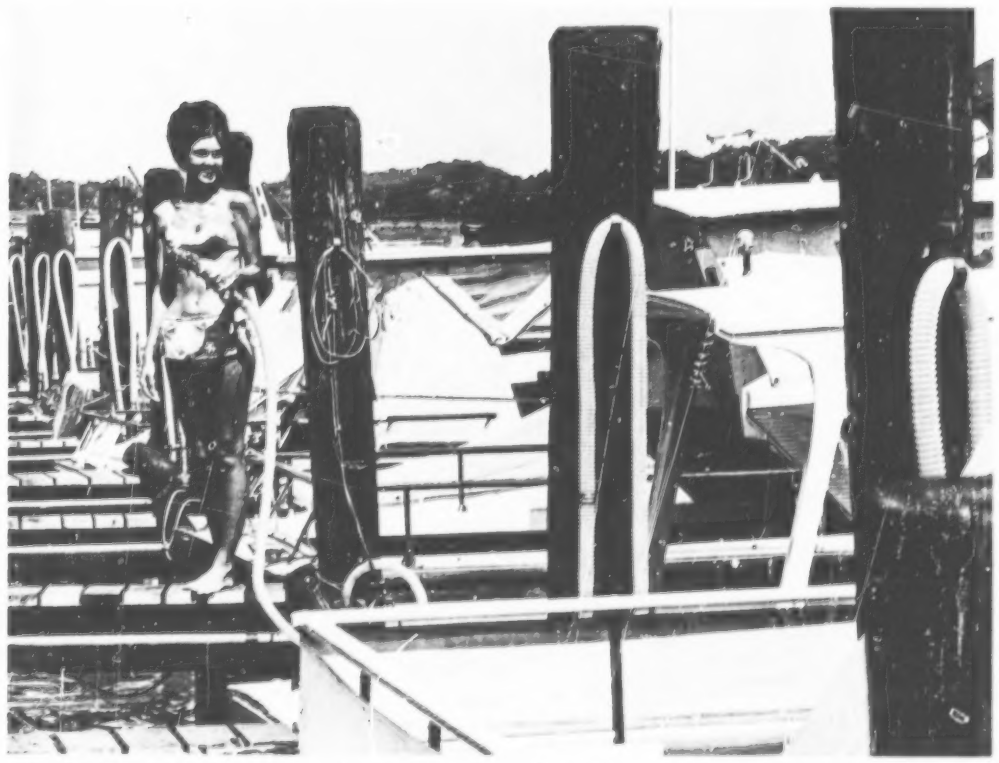


FIGURE 9. Marina boat slips, hose and piping connection.

water storage facilities. This will result in continual sewage treatment plant operation, which will reflect a better quality effluent since the plant will not be required to handle intermittent shock loadings.

SECTION 10

COST ESTIMATES

The estimated cost to provide a boat having a head and galley with a kit consisting of a holding tank, deck plate, piping, fittings and valve is less than one-hundred dollars. Additional cost is incurred with the addition of a macerator, pump and electrical switches and wiring. These added costs amount to approximately seventy-five dollars, however, if pumping facility is always available at dockside, there is no reason to provide macerator and pump in the boat. This will simplify the problem to the boat owner because of elimination of all mechanical and electrical devices. Also, this arrangement will be foolproof and will have more market acceptance. Less possibility of river pollution will result since boats would have no facilities for pumping waste overboard.

Cost for a marina installation is based on configuration of the marina, location of service platform with respect to the farthest slip, construction of walkways, power availability, dredging depth, underwater tank location, main pump location, etc.

Estimated cost for a waste collection system for a ninety-six boat marina with six slips back-to-back, sixteen boats per slip,

and the service station in the center would be as tabulated in Table VI on page 51.

With larger marinas, the estimated construction cost for a waste collection system would be reduced, inasmuch as such items of cost as the underwater storage tank, main pump station, underwater piping, dredging and construction equipment, the sum of which accounts for one-half the total cost, do not increase proportionately with the number of boats. For example, the installation cost for a 150-boat marina would be approximately $78,000.00 or $520.00 per boat, instead of $620.00 per boat as estimated for the 96-boat marina. A two hundred boat marina installation would drop to an estimated $475.00 per boat.

Revenue to the marina operator could be achieved by a charge (say $10.00 per month) to each boat owner occupying the 96-boat slip for the use of dockside pumping and macerator stations. Income for a five-month season on this basis would be $4,800.00. Additional revenue could be realized through transient boats pumped out at the main service platform. Based on forty boats per week over a 22-week operating season at a reasonable charge of five dollars per flush, the revenue from this source is estimated at $4,400.00. Total revenue to the marina operator

TABLE VI

COST ESTIMATED FOR 96 BOAT MARINA

Marina Dockside Coin Operated Pumping and Macerator Stations (One per Finger Pier)	6 ea. @ $800	$4,800
Hose Stations	96 ea. @ $ 50	4,800
Dockside Sewage Collection System	1,500 LF @ $ 5	7,500
Underwater Storage Tank (6,000 gallon) including Anchors and Supports	1 ea.	7,500
Dredging, including Equipment Rental		2,500
Main Pumping Station		5,000
Underwater Piping	200 LF @ $ 18	3,600
Electrical Work		3,500
Construction Equipment		2,000
Total		$41,200
Contingencies		8,000
Construction Overhead and Profit		12,800
Total Estimated Cost		$62,000

on this estimate is $9,200.00 per season or approximately 15% of estimated cost of installation. With larger marinas, return to the operator would be proportionately greater.

SECTION 11

ACKNOWLEDGEMENTS

This demonstration facility was carried out by the Underwater Storage, Inc., Silver, Schwartz, Ltd. Joint Venture under contract No. 14-12-493 for the Federal Water Pollution Control Administration, Department of the Interior.

The concept of underwater storage of sanitary waste was originally conceived by Dr. Harold G. Quase, President of Underwater Storage, Inc. Proprietary items used in the formulation of this project are based on patents assigned to Underwater Storage, Inc., by Dr. Quase.

Acknowledgement is made of the support and assistance of those who participated directly in this effort:

Mr. Grover E. Steele and Mr. Robert Viklund of the National Capitol Park Service, Department of the Interior, for their efforts in all aspects of construction and operation of the project.

Mr. Thomas Long and his staff at the marina for permitting their facilities to be used and for their assistance during construction of the project.

Goodyear Tire and Rubber Company, Industrial Products Division, for the expeditious manner in which the underwater storage tank was fabricated and delivered to the site.

Mr. G. J. Maliszewski of the Potomac Electric Power Company for his personal efforts in providing electric service to the site on short notice.

Dr. Harold M. Windlan of The C. W. England Laboratories, Inc. for giving the project immediate service in processing of chemical analyses of waste samples.

The ten boat owners for their indulgence and cooperation throughout the period when boats were being modified and during the operational phase of the project.

Special thanks are given to Dr. James Shackelford and Mr. Patrick Tobin of Federal Water Pollution Control Administration for their comments during the course of the program, which provided valuable guidance in evaluation of the system.

The project was administered and supervised by Underwater Storage, Inc. Dr. Harold G. Quase was Project Director and H. C. John Russell was Project Supervisor.

The project was designed and operated by Silver, Schwartz, Ltd. Sidney A. Silver, P.E. was Chief Engineer, Harold Schwartz, P.E. was Design Engineer, and Irving T. Read was the Field Engineer.

SECTION 12

PATENTS AND PAPERS

Patent No. 3,114,468 - H. G. Quase assignor to Underwater Storage, Inc. "Collapsible Container," dated December 17, 1963.

Patent No. 3,114,384 - H. G. Quase assignor to Underwater Storage, Inc. "Underwater Storage System," dated December 17, 1963.

Patent No. 3,155,280 - H. G. Quase assignor to Underwater Storage, Inc. "Buoyant Flexible Container and Underwater Anchorage Therefor," dated November 3, 1964.

Patent No. 3,187,793 - H. G. Quase assignor to Underwater Storage, Inc. "Amphibious Underwater Storage System," dated June 8, 1965.

Paper prepared by Underwater Storage, Inc. "Treatment of Watercraft Waste at Boat Marinas."

Remarks by Sidney A. Silver, P.E., at Demonstration of Marina Underwater Waste Collection System, dated June 20, 1969.

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American Public Health Association. Standard Methods for Examination of Water and Wastewater. 12th Ed. New York: 1965.

Babbitt and Baumann, Sewerage and Sewage Treatment. New York: John Wiley and Sons.

Hertzberg, R.H., Waste Disposal from Watercraft, Journal, Water Pollution Control Federation. December, 1968.

National Sanitation Foundation. Standard No. 23, Watercraft Sewage Disposal Devices. Ann Arbor, Michigan: May, 1968.

Pollution from Vessels Threaten to Negate Clean Water Goals. Environmental Science and Technology. 1968.

Seelye, Elwyn E., Data Book for Civil Engineers, Vol. 1, Design. New York: John Wiley and Sons.

United States Department of the Interior, Federal Water Pollution Control Administration, Report to the Congress of the United States, Wastes from Watercraft, Document No. 48. August 7, 1967.

FIGURE NO. 10

Site Plan Showing Boat Slips, Marina Administration Building, Pump House and Underwater Storage Tank Location.

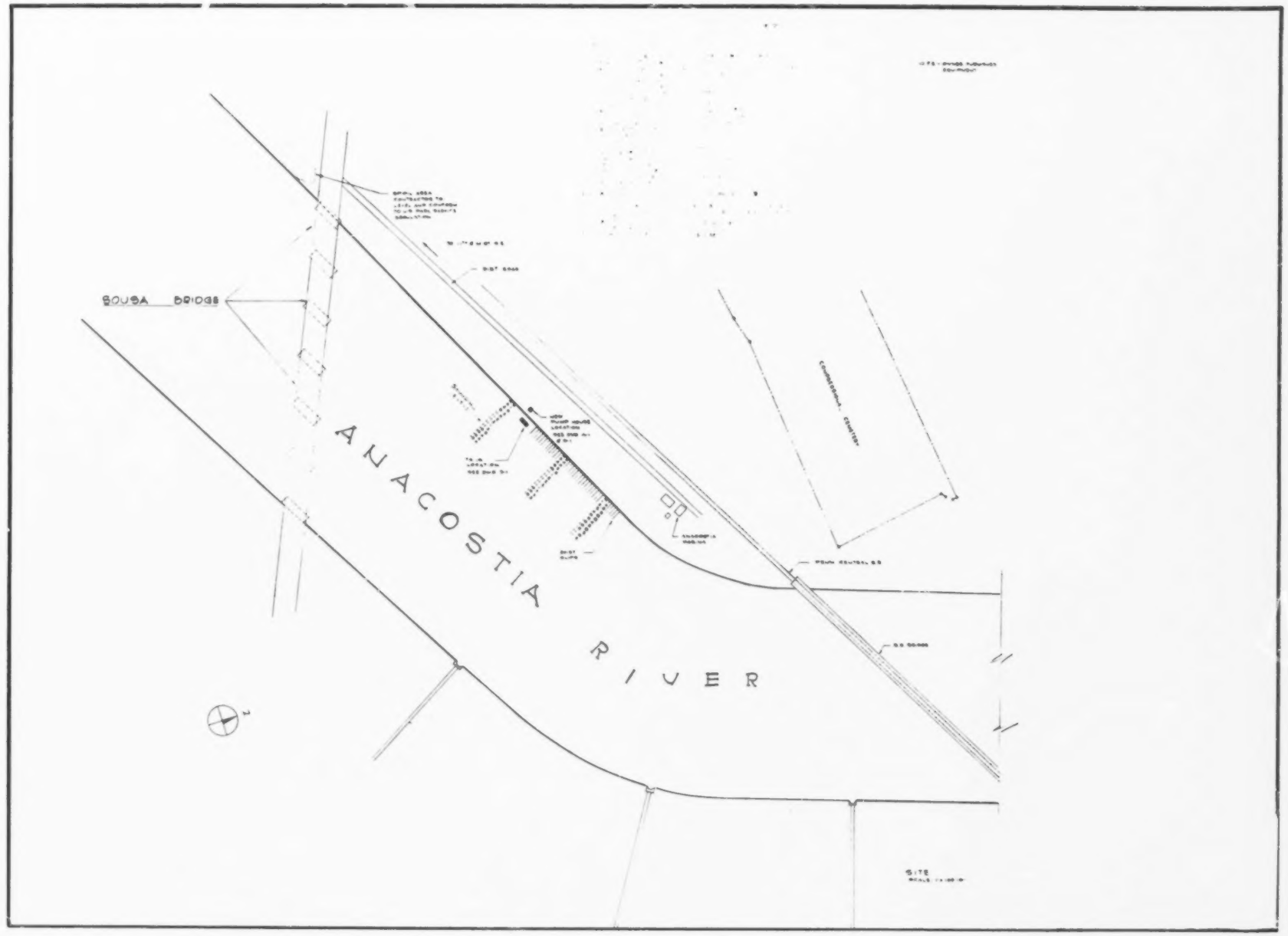
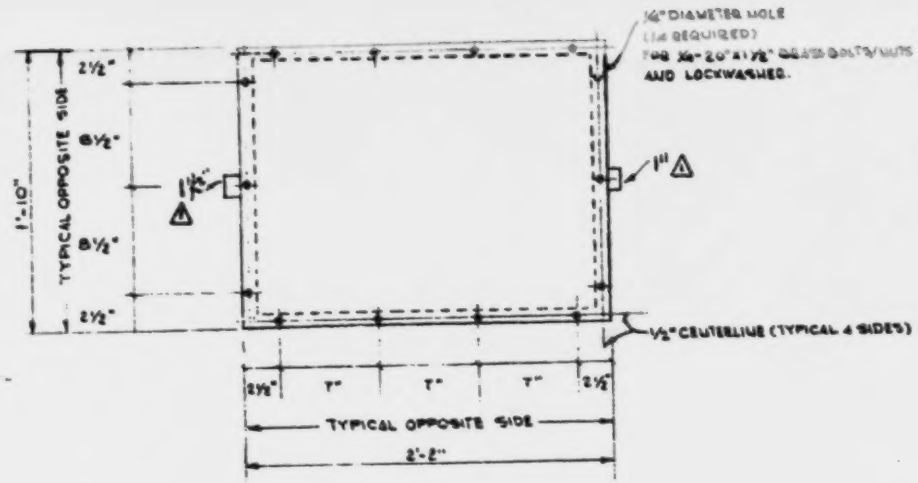


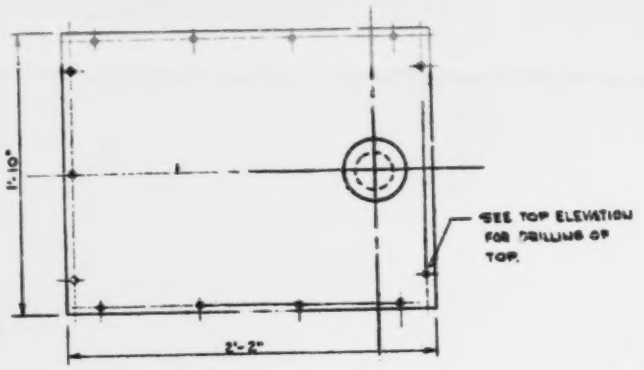
Figure 10:

FIGURE NO. 11

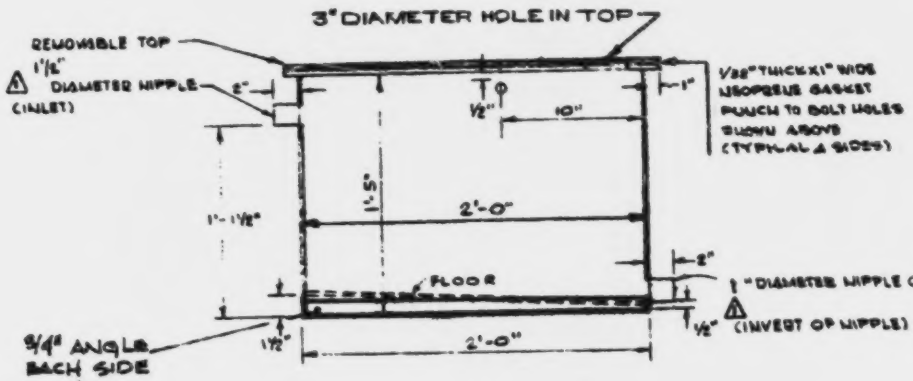
On-Board Boat Holding Tank Detail.



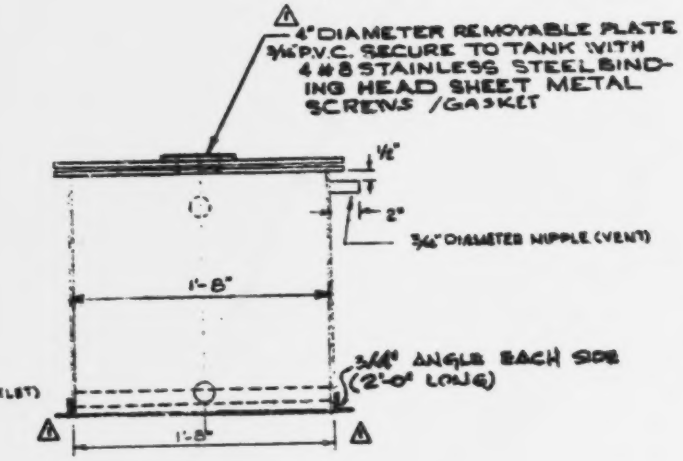
TOP ELEVATION



REMOVABLE TOP



SIDE ELEVATION


4" DIAMETER REMOVABLE PLATE 3/16" P.V.C. SECURE TO TANK WITH 4 #8 STAINLESS STEEL BINDING HEAD SHEET METAL SCREWS /GASKET
1/2"
2"
3/4" DIAMETER NIPPLE (VENT)
1'-8"
3/4" ANGLE EACH SIDE (2'-0" LONG)
1'-8"

END ELEVATION

1. CONSTRUCTION OF TANK SHALL BE MINIMUM 3/16" THICKNESS P.V.C.
2. ALL NIPPLES ARE I.P.S.
3. PROVIDE NECESSARY STIFFENERS TO MAINTAIN TANK AND NIPPLES.
4. TANK SHALL BE RATED FOR "0" PRESSURE
5. 10 UNITS REQUIRED

SCALE 1 1/2" = 1'

Figure 11:

FIGURE NO. 12

Typical Boat Plan Showing All Fixtures, On-Board Holding Tank, and Boat Wiring Diagram for Transfer Pump and Macerator.

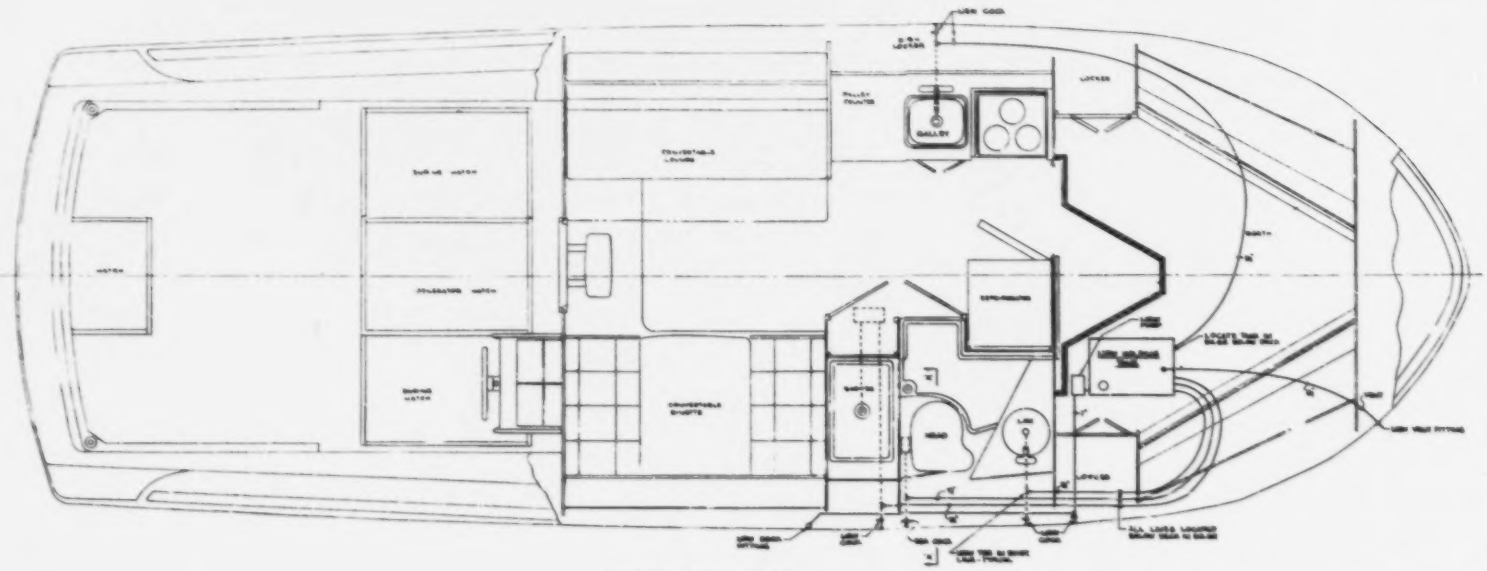


Figure 12:

FIGURE NO. 13

Boat Components Plan Showing Fixtures Connected to Boat Holding Tank, Macerator, Transfer Pump, Discharge Line to Deck Plate, Vent and Dump Lines.

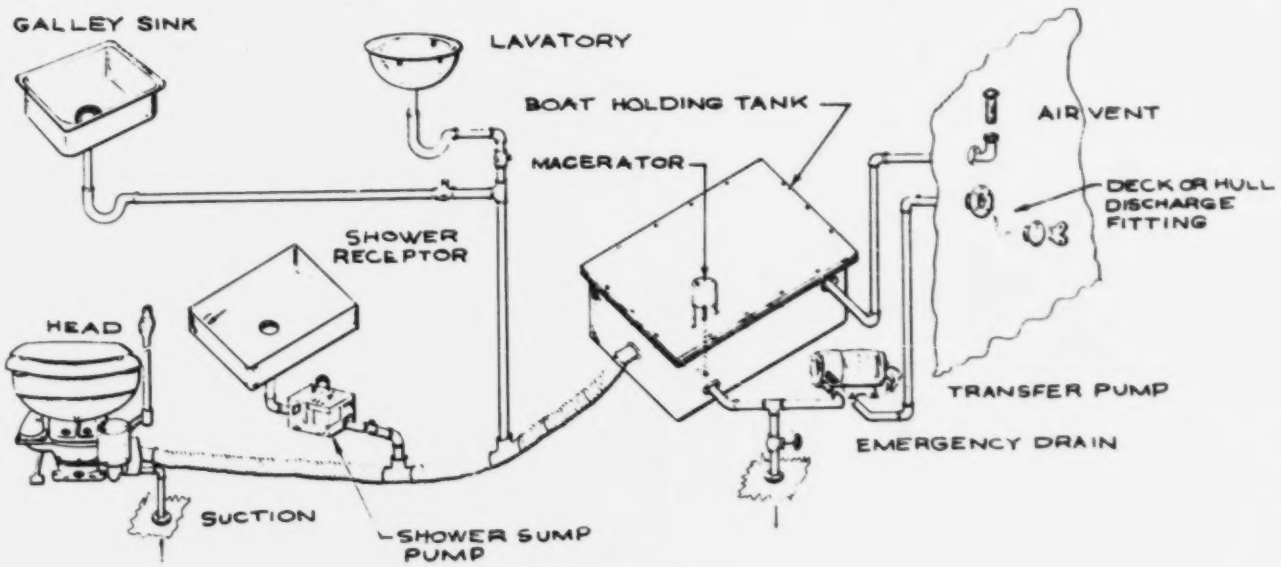

GALLEY SINK
LAVATORY
BOAT HOLDING TANK
MACERATOR
AIR VENT
DECK OR HULL DISCHARGE FITTING
SHOWER RECEPTOR
HEAD
TRANSFER PUMP
EMERGENCY DRAIN
SUCTION
SHOWER SUMP PUMP

Figure 13:

FIGURE NO. 14

Pier Plan Showing Ten Boat Slips and Piping, Meter and Sampling Station, Electrical and Mechanical Facilities in Pump House.

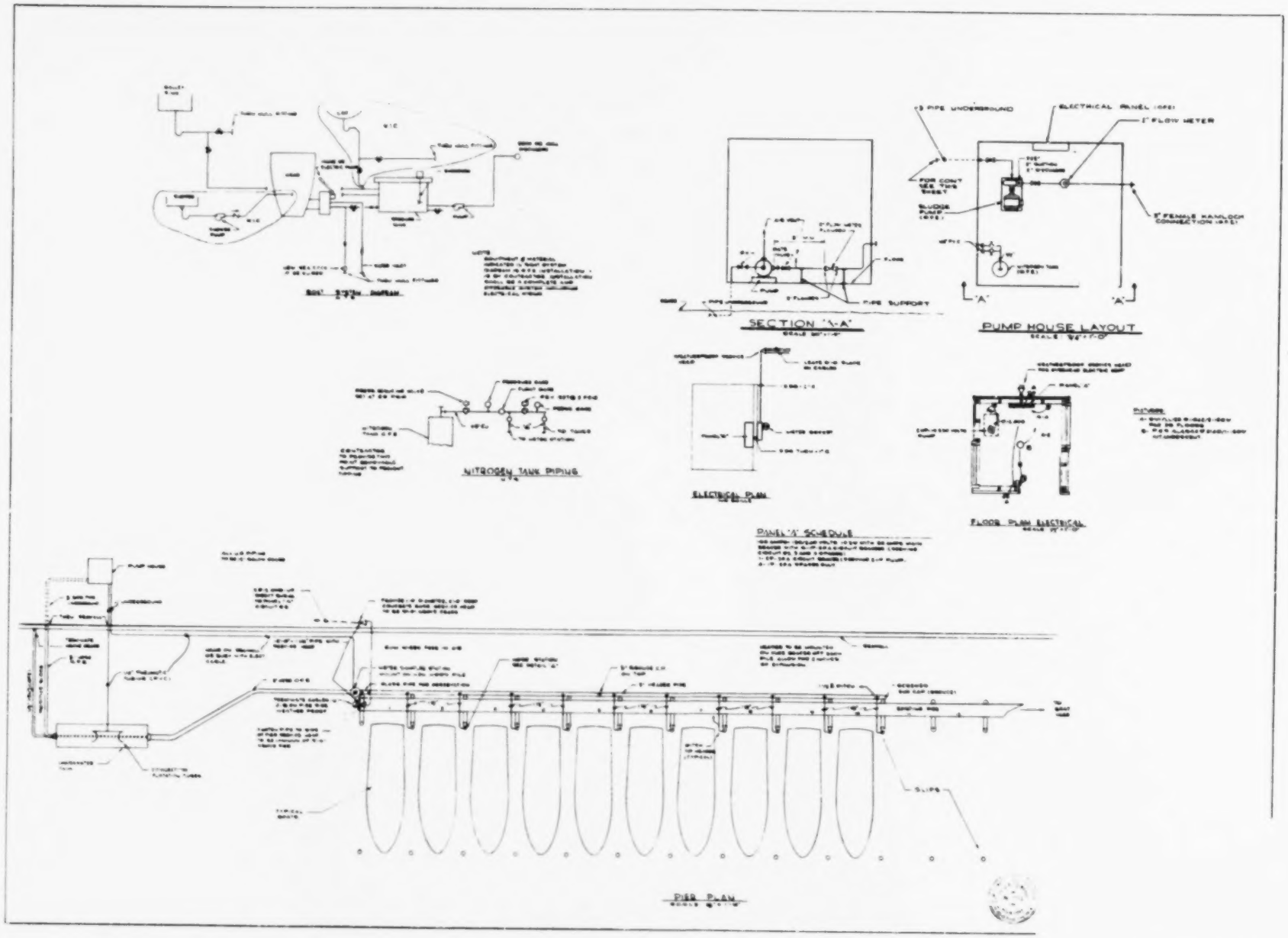
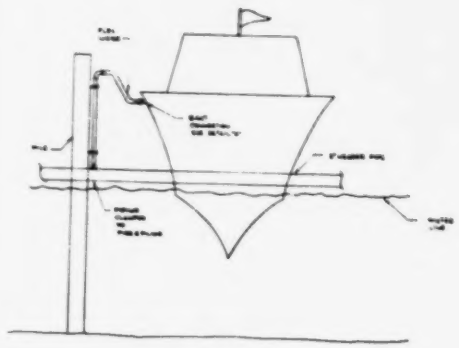

NITROGEN TANK PIPING
SECTION 'A-A'
PUMP HOUSE LAYOUT
ELECTRICAL PLAN
FLOOR PLAN ELECTRICAL
PANEL 'A' SCHEDULE
PIER PLAN

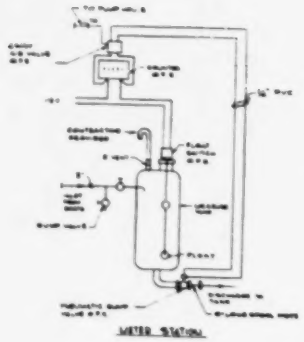
Figure 14:

FIGURE NO. 15

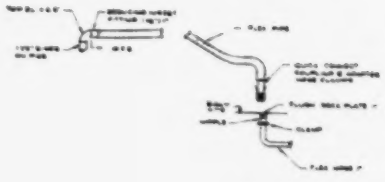
Underwater Storage Tank Detail Showing Meter Station Details and Boat Connections to Dock-side Piping.



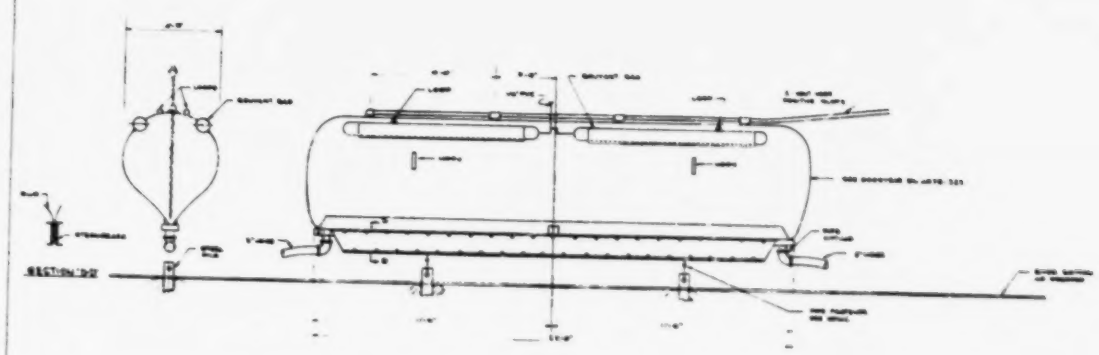
DETAIL 'A'



METER STATION



DETAIL 'X'



UNDERWATER TANK DETAIL

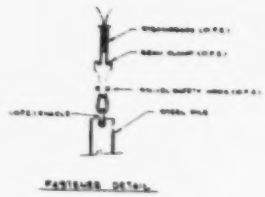


Figure 15:

FIGURE NO. 16

Underwater Storage Tank Excavation and Dredging Plan, and Location Plan Showing Location of Tank with Respect to Pier and Pump House.

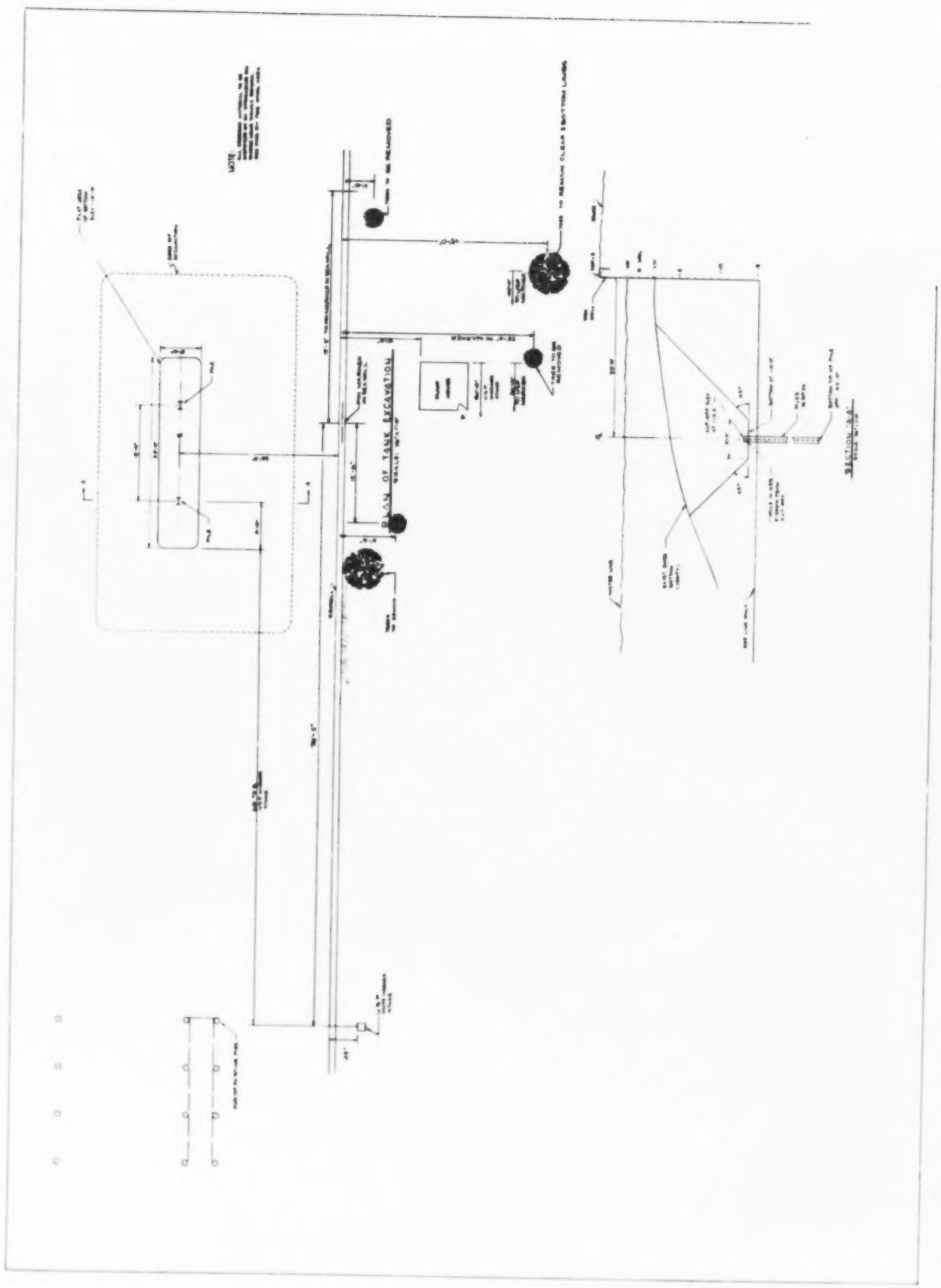


Figure 16:

FIGURE NO. 17

Pump House Architectural Plan Showing Stained Frame Building with Cedar Shake Roof, Built Approximately 15-inches Above Grade.

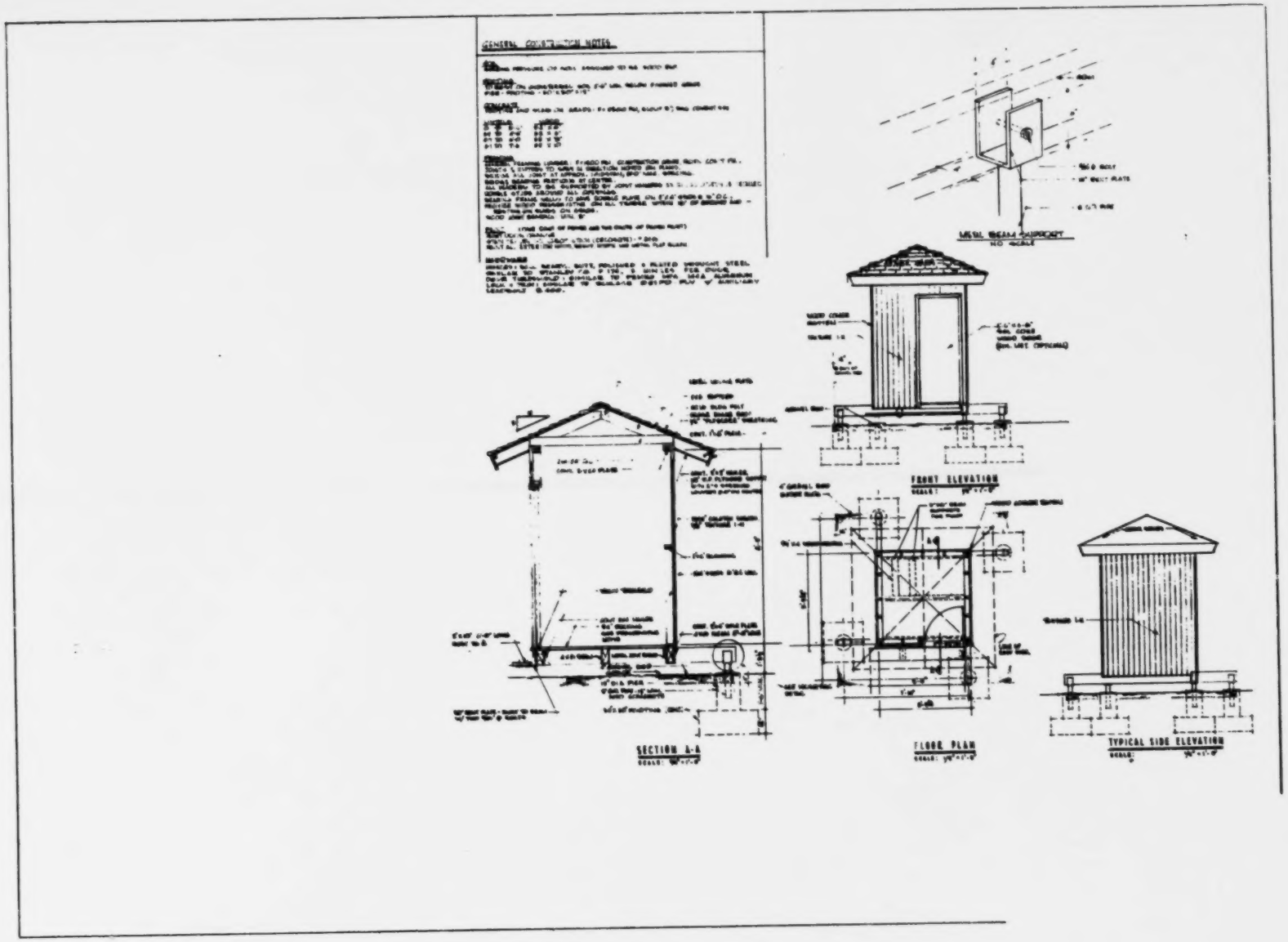

GENERAL CONSTRUCTION NOTES
SECTION A-A
FLOOR PLAN
FRONT ELEVATION
TYPICAL SIDE ELEVATION

Figure 17:

As the Nation's principal conservation agency, the Department of the Interior has basic responsibilities for water, fish, wildlife, mineral, land, park, and recreational resources. Indian and Territorial affairs are other major concerns of America's "Department of Natural Resources."

The Department works to assure the wisest choice in managing all our resources so each will make its full contribution to a better United States—now and in the future.

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